Cognitive Architecture Usability

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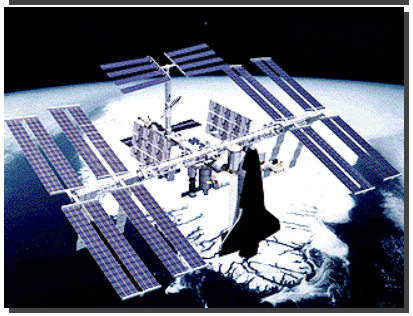
NASA Human Simulation Applications



- Evaluating cockpit designs
- Planning crewed missions
- Artificial participants in training simulations
- Technology impact assessment

Problem:

Demand for human simulation models exceeds what modelers can supply with current tools

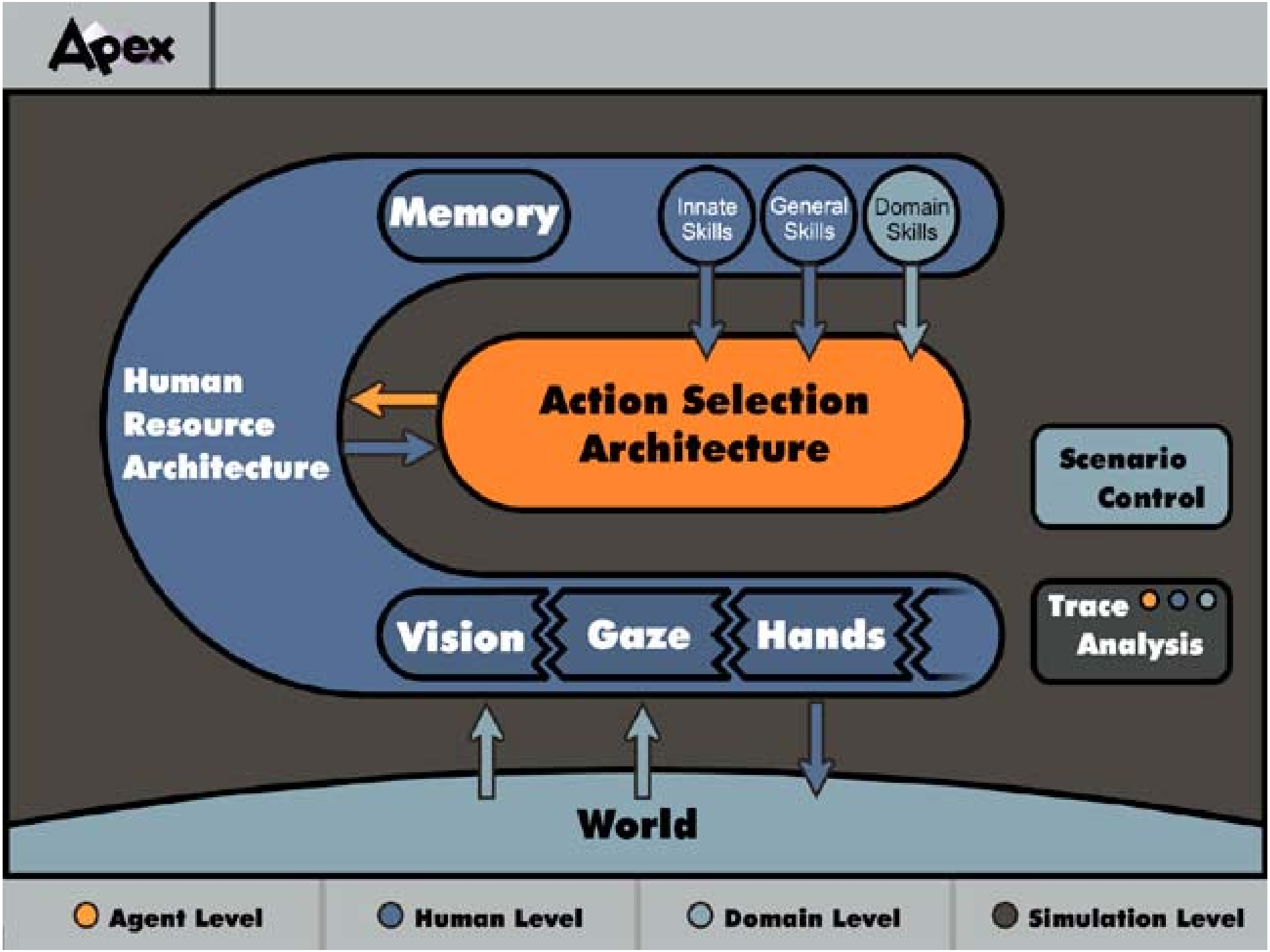
Human Simulation Tools

Challenges

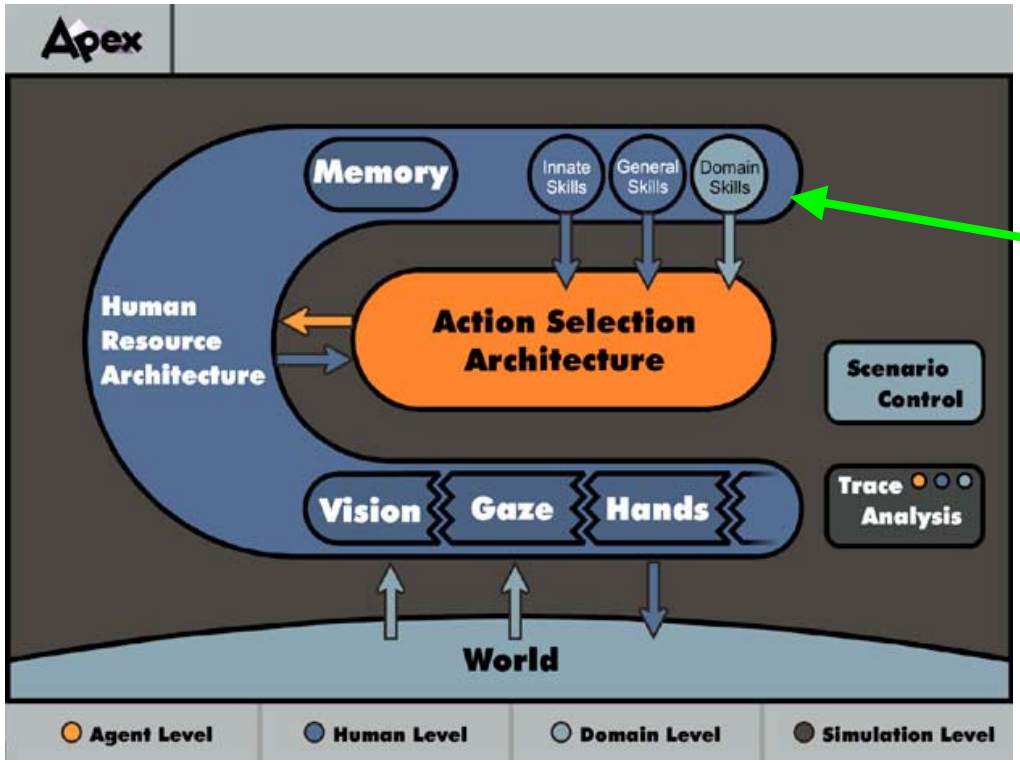
Goal in developing Apex has been to provide practical tool addressing 3 central challenges:

- Robust, intelligent behavior
- Valid, useful predictions
- Minimum time/expertise to build models

Apex


Apex
Memory
Innate Skills
General Skills
Domain Skills
Human Resource Architecture
Action Selection Architecture
Scenario Control
Trace
Analysis
Vision
Gaze
Hands
World
Agent Level
Human Level
Domain Level
Simulation Level

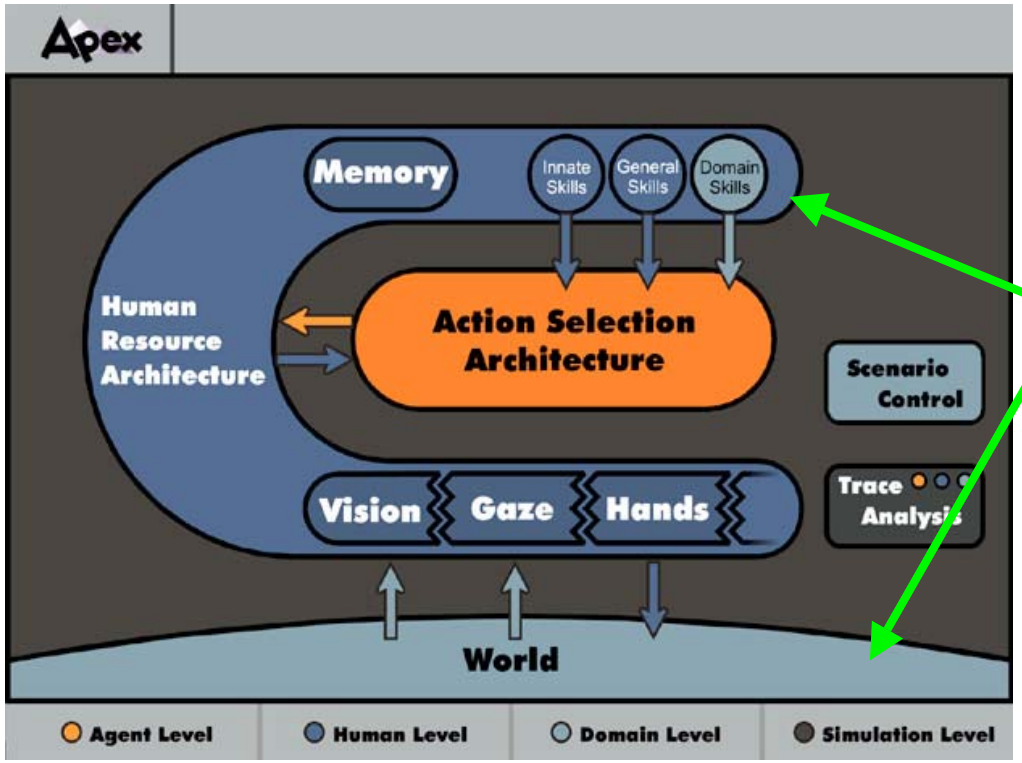
Reducing time/expertise to construct models



Usability efforts

- High-level language

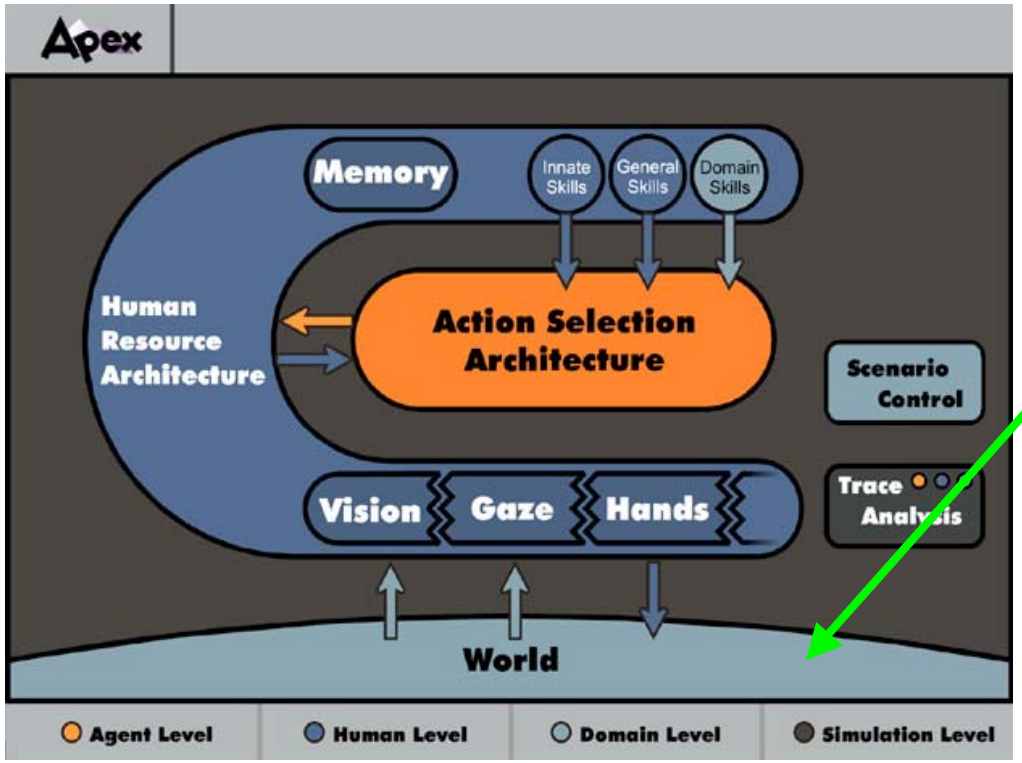
Reducing time/expertise to construct models



Usability efforts

- High-level language
- Visualization/debug tools

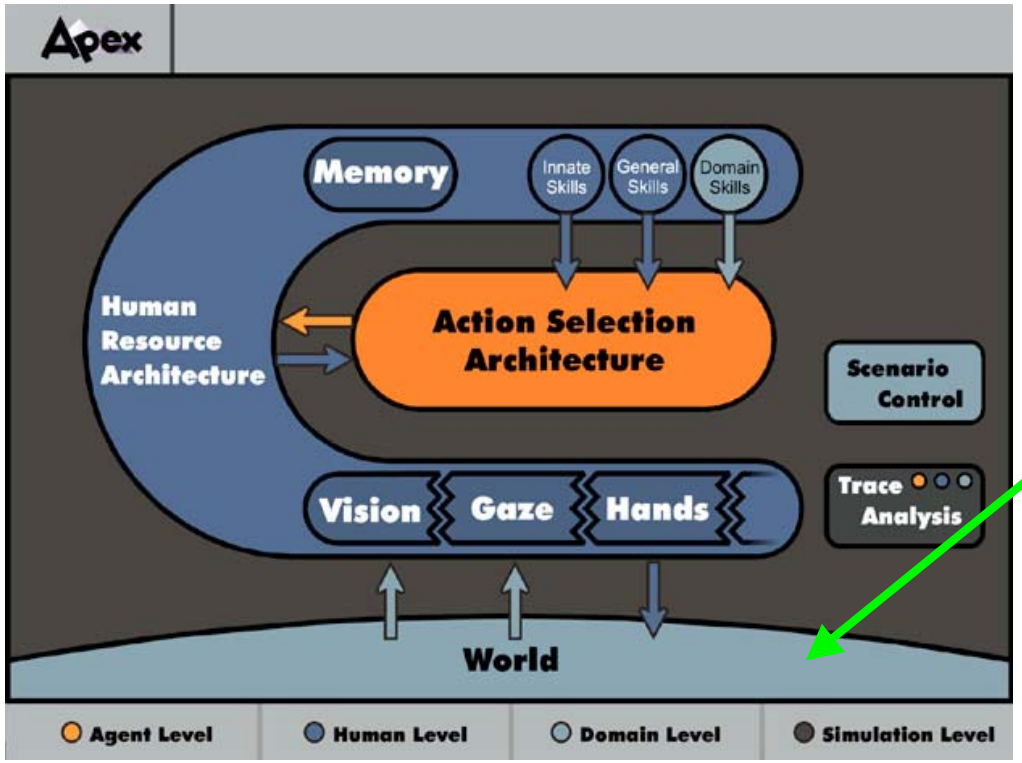
Reducing time/expertise to construct models



Usability efforts

- High-level language
- Visualization/debug tools
- World modeling

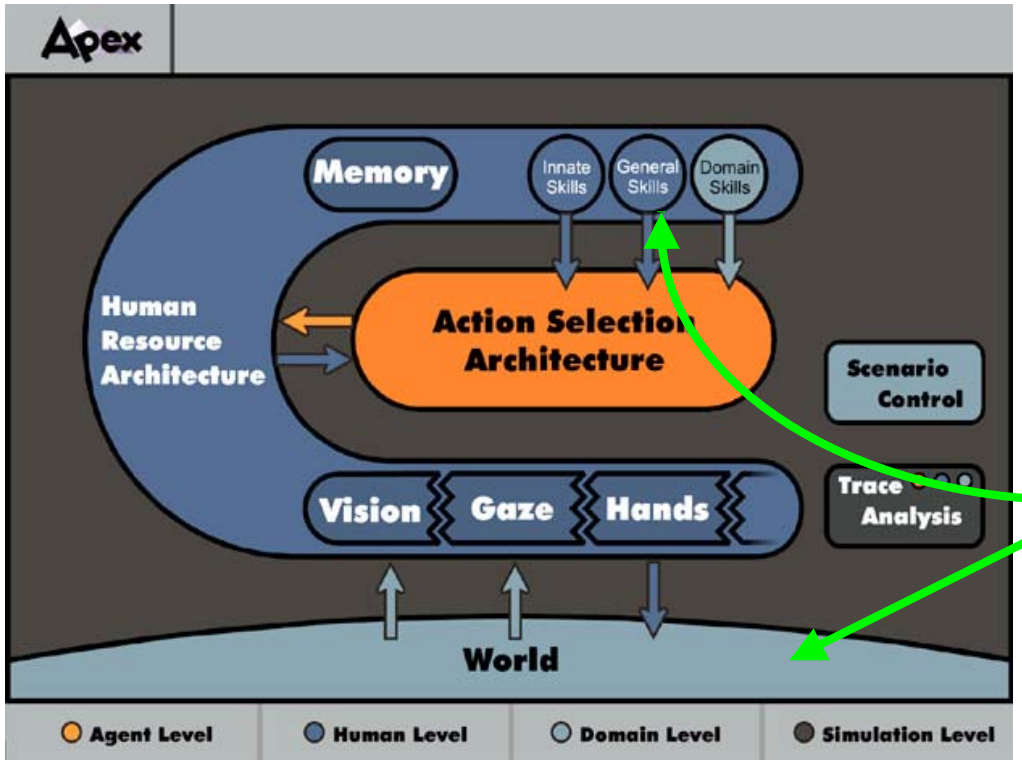
Reducing time/expertise to construct models



Usability efforts

- High-level language
- Visualization/debug tools
- World modeling
- Interoperability

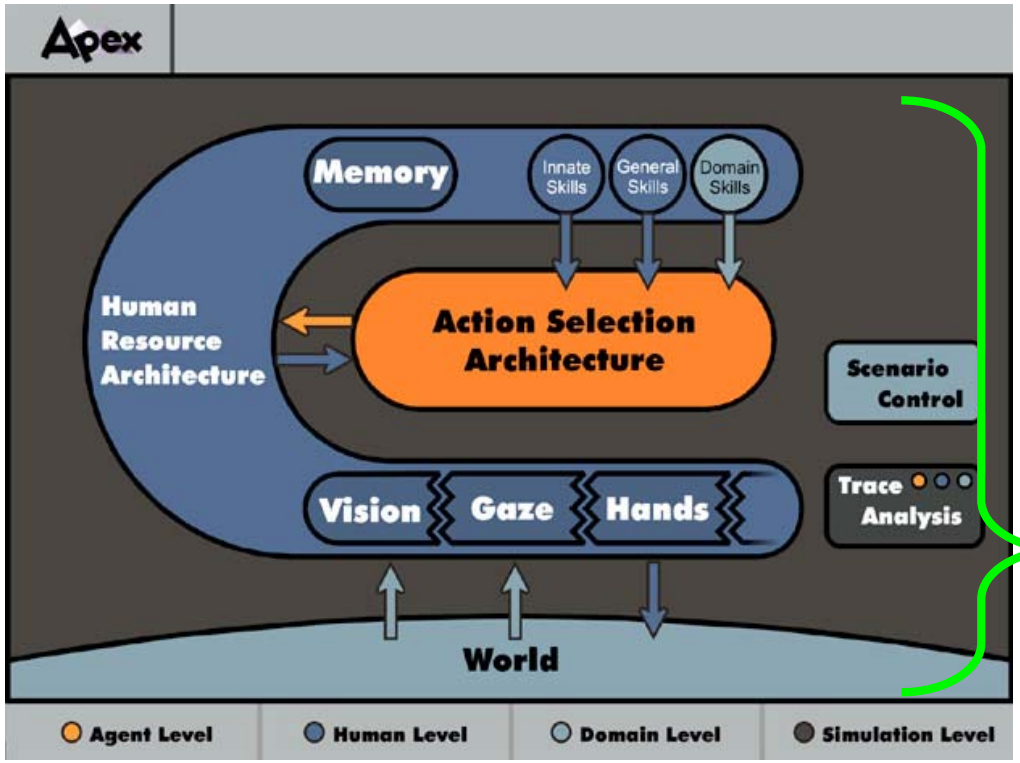
Reducing time/expertise to construct models



Usability efforts

- High-level language
- Visualization/debug tools
- World modeling
- Interoperability
- Reusable components

Reducing time/expertise to construct models



Usability efforts

- High-level language
- Visualization/debug tools
- World modeling
- Interoperability
- Reusable components
- Distributed development

NASA Apex

High-level behavior representation

Procedure Definition Language

```
(procedure
   (index (hold-altitude using mcp))
   (profile right-hand)
   (step s1 (clear right-hand))
   (step s2 (find-loc alt-hold-button => ?loc))
   (step s3 (press-button ?loc right-hand)
      (waitfor (empty right-hand)
               (location alt-hold-button ?loc)))
   (step end (terminate)
      (waitfor (illuminated alt-hold-button))
   (step aux1 (restart ?self)
      (waitfor (resumed ?self))))
```

- concurrency
- reactivity
- hierarchy
- contingency-handling

Apex

Behavior representation: usability

Intuitive

(step s3 (stop) (waitfor (shape ?x light) (color ?x red)))

conjunctive preconditions mutually constraining

Expressive

(step s4 (slow) (waitfor (color ?x green) then (color ?x yellow))

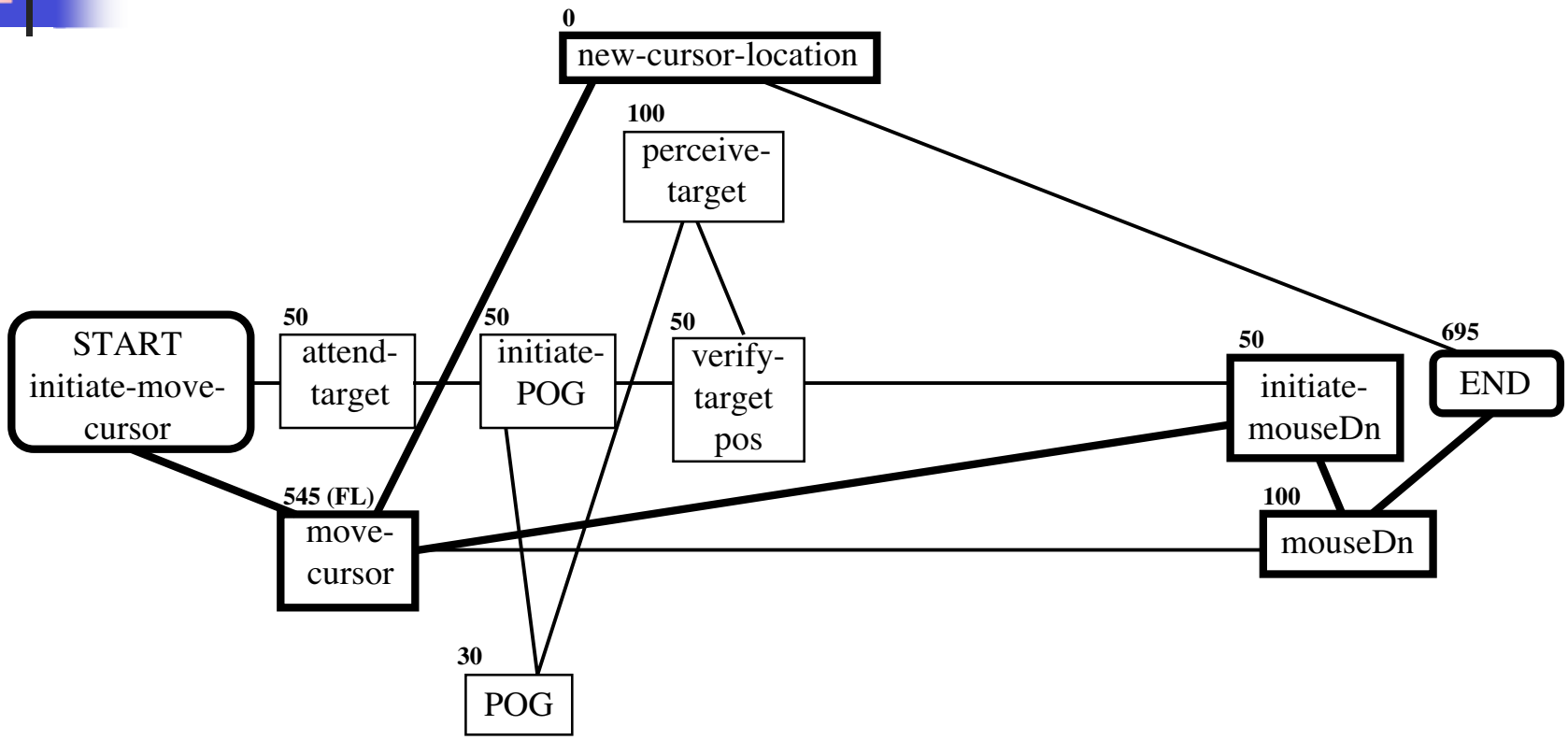
able to express temporal relations between preconditions

Compact

abbreviated form for sequential procedures

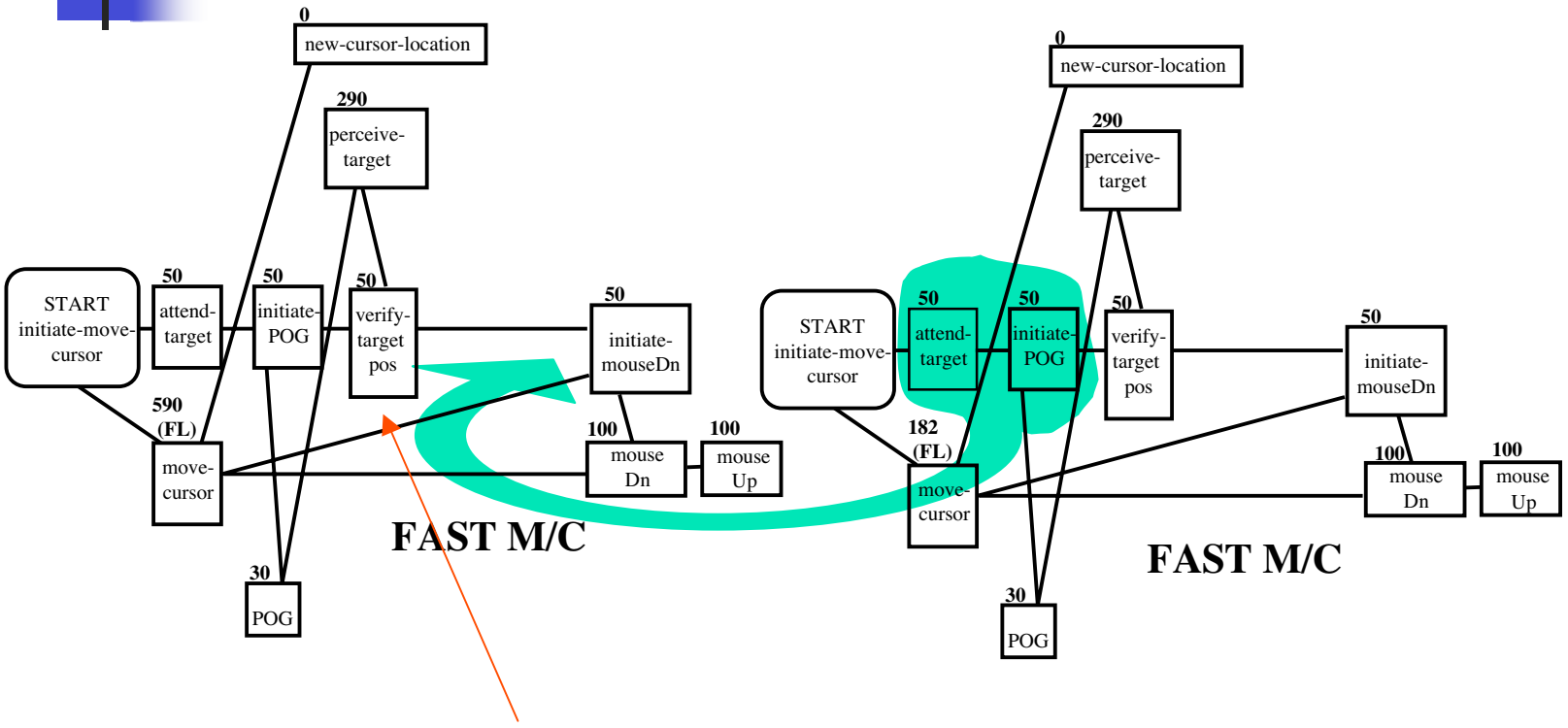
Evolves as users' needs become better understood

FAST MOVE-CLICK

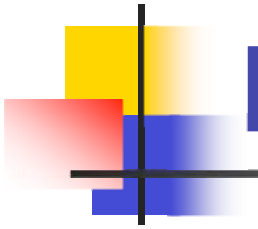


- from *Gray and Boehm-Davis (2000)*

Interleaving Templates



last vision action in the previous operator



How PDL specifies interleaving

CPM-GOMS requires that actions from templates earlier in a template sequence have priority in resource conflicts over activities from later templates.

Initial approach used the `priority` clause:

- determines how to resolve resource conflict
- globally scoped to allow comparison of any tasks

```
(step s2 (turn off alarm)
  (waitfor (on alarm))
  (priority 5))
```

How PDL specifies interleaving

Global scope of priority value assignments undesirable for CPM-GOMS representations

```
(procedure
  (index (get ?amt from atm))
  (step s1 (init atm transaction)
          (priority 3000))
  (step s2 (withdraw ?amt))
          (priority 2000))
  (step s3 (end atm transaction)
          (priority 1000))
  (step s4 (terminate) (waitfor ?s3)))
```

```
(procedure
  (index (init atm transaction))
  (step s1 (insert card)
     (priority 3200))
  (step s2 (enter password)
     (priority 3100))
  (step s3 (terminate)
     (waitfor ?s2)))
```

Complex procedure to set priority values

Requires modeler to anticipate decomposition

How PDL specifies interleaving

Solution alternative mechanisms/syntax for resolving resource conflicts that is dynamically scoped

```
(procedure
  (index (get ?amt from atm))
  (step s1 (init atm transaction)
           (rank 1))
  (step s2 (withdraw ?amt))
           (rank 2))
  (step s3 (end atm transaction)
           (rank 3))
  (step s4 (terminate) (waitfor ?s3)))
```

```
(procedure
  (index (init atm transaction))
  (step s1 (insert card)
     (rank 1))
  (step s2 (enter password)
     (rank 2))
  (step s3 (terminate)
     (waitfor ?s2)))
```

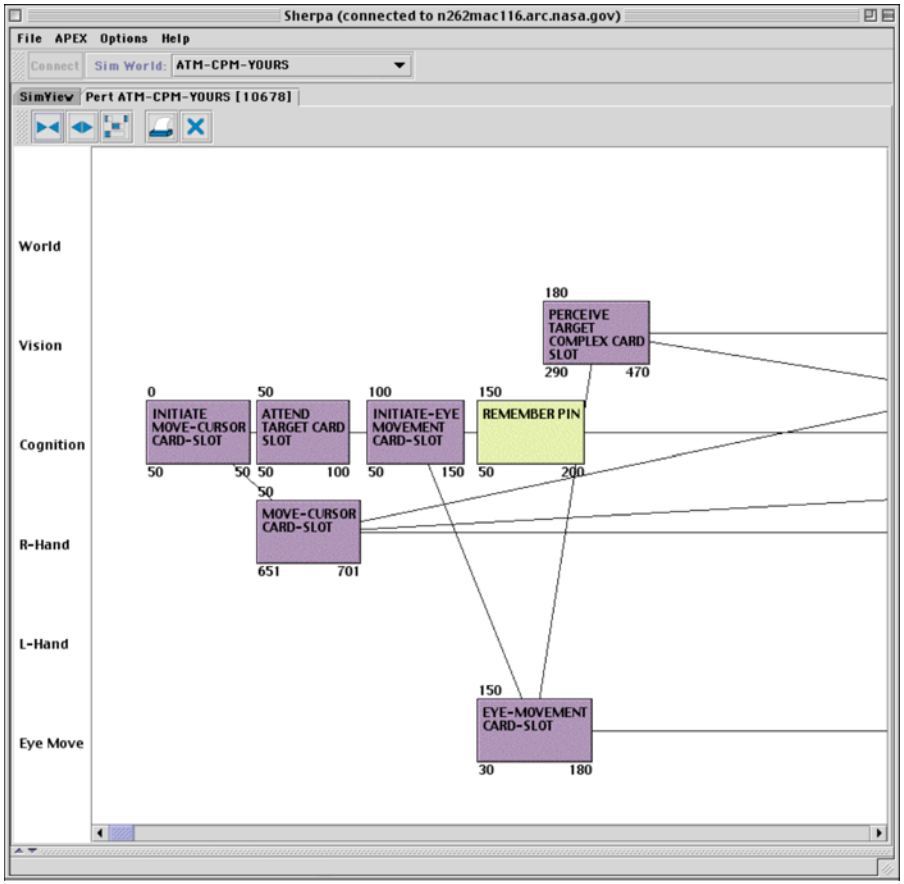
How PDL specifies interleaving

Abbreviation to further simplify syntax…

```
(procedure :ranked
  (index (get ?amt from atm))
  (step s1 (init atm transaction)
  (step s2 (withdraw ?amt))
  (step s3 (end atm transaction)
  (step s4 (terminate) (waitfor ?s3)))
```

```
(procedure :ranked
  (index (init atm transaction))
  (step s1 (insert card)
  (step s2 (enter password)
  (step s3 (terminate)
     (waitfor ?s2)))
```

Visualizing and Debugging



Sherpa

- **Simulation traces**
- **Physical environment**
- **PERT charts**

VISTA

- **Enhanced Sim Trace**

  (2001 CMU student project)

Specifying a Physical World Model

Time-consuming and error-prone when done by hand

C:\apex\worlds\atm-klm-world\initializeOrig.lisp

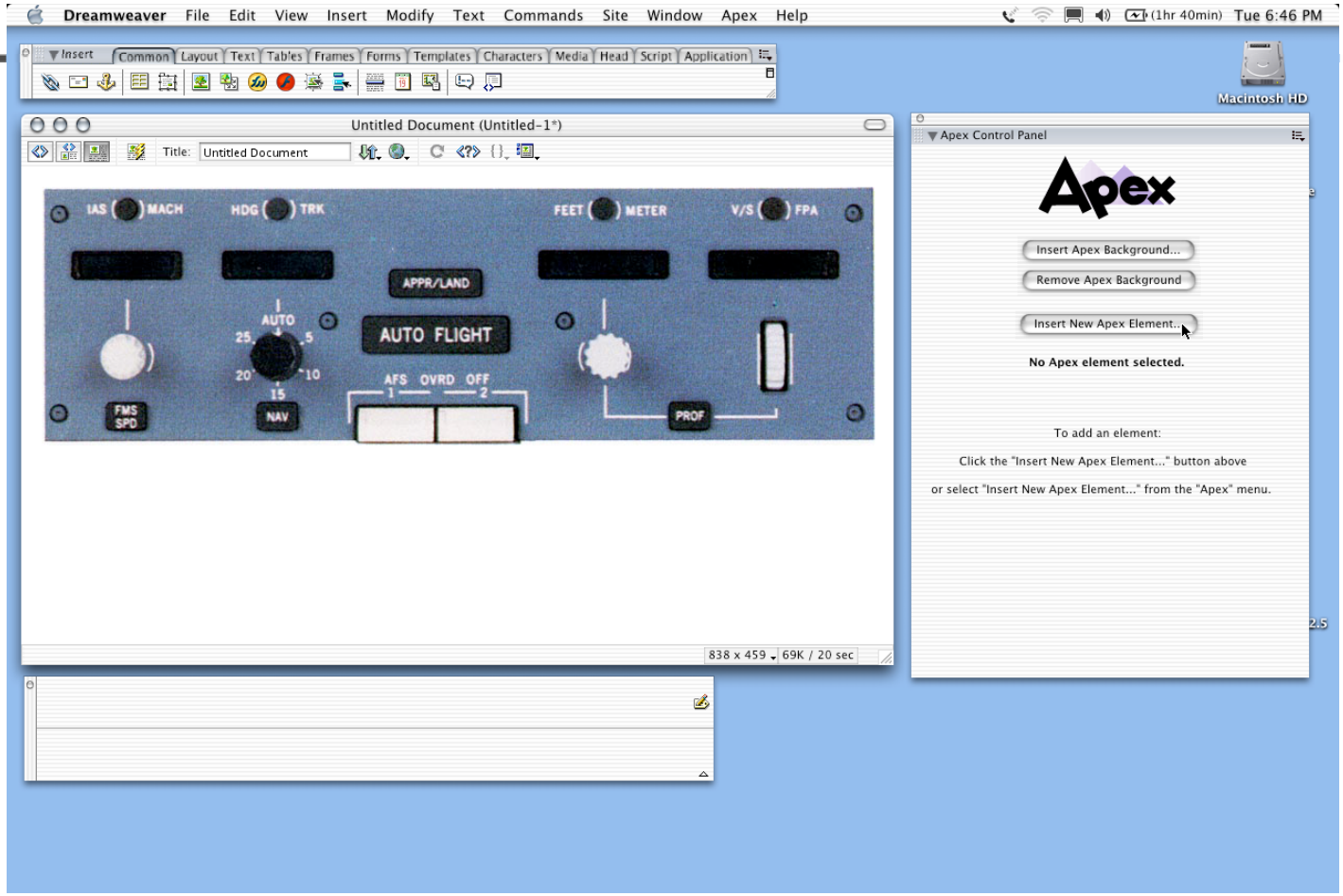
```
;;;;;;;;;;;;;;;;;;;;;;;;;;
; ATM World Initialization
; positions and dimensions are in units of millimeters

(in-package :common-lisp-user)

(initialize-simulation
  (let*
      ((bank (make-instance 'locale :name 'bank))
       (human (make-instance 'human :name 'agent :locale bank
                             :location '(0 0 22)))
       (atm (make-instance 'atm :name 'atm :locale bank
                           :pos '(0 0) :dimensions '(182 164)))
       (money-slot (make-instance 'money-slot :name 'money-slot :locale bank
                                  :pos '(11 9) :dimensions '(98 2)))
       (screen (make-instance 'screen :name 'screen :locale bank
                              :pos '(21 23) :dimensions '(108 68)))
       (checking (make-instance 'button :name 'checking-key :locale bank
                                :pos '(131 51) :dimensions '(15 11)))
       (withdraw (make-instance 'button :name 'withdraw-key :locale bank
                                :pos '(131 66) :dimensions '(15 11)))
       (correct (make-instance 'button :name 'correct-key :locale bank
                               :pos '(131 66) :dimensions '(15 11)))
       (no (make-instance 'button :name 'no-key :locale bank
                          :pos '(131 81) :dimensions '(15 11)))
       (keypad (create-keypad '(43 104) '(13 11) '(4 2) 'down bank))
       (ok (make-instance 'button :name 'ok-key :locale bank
                          :pos '(95 129) :dimensions '(15 11)))
       (card-slot (make-instance 'card-slot :name 'card-slot :locale bank
                                 :pos '(131 127) :dimensions '(43 2)))
       (mouse (create-mouse bank))
       )
    ;; assemble top level objects
    (mapc #'assemble (list human atm))
    ;; assemble components of ATM
    (mapc #'(lambda (obj) (assemble obj :component-of atm))
```

Specifying a Physical World Model

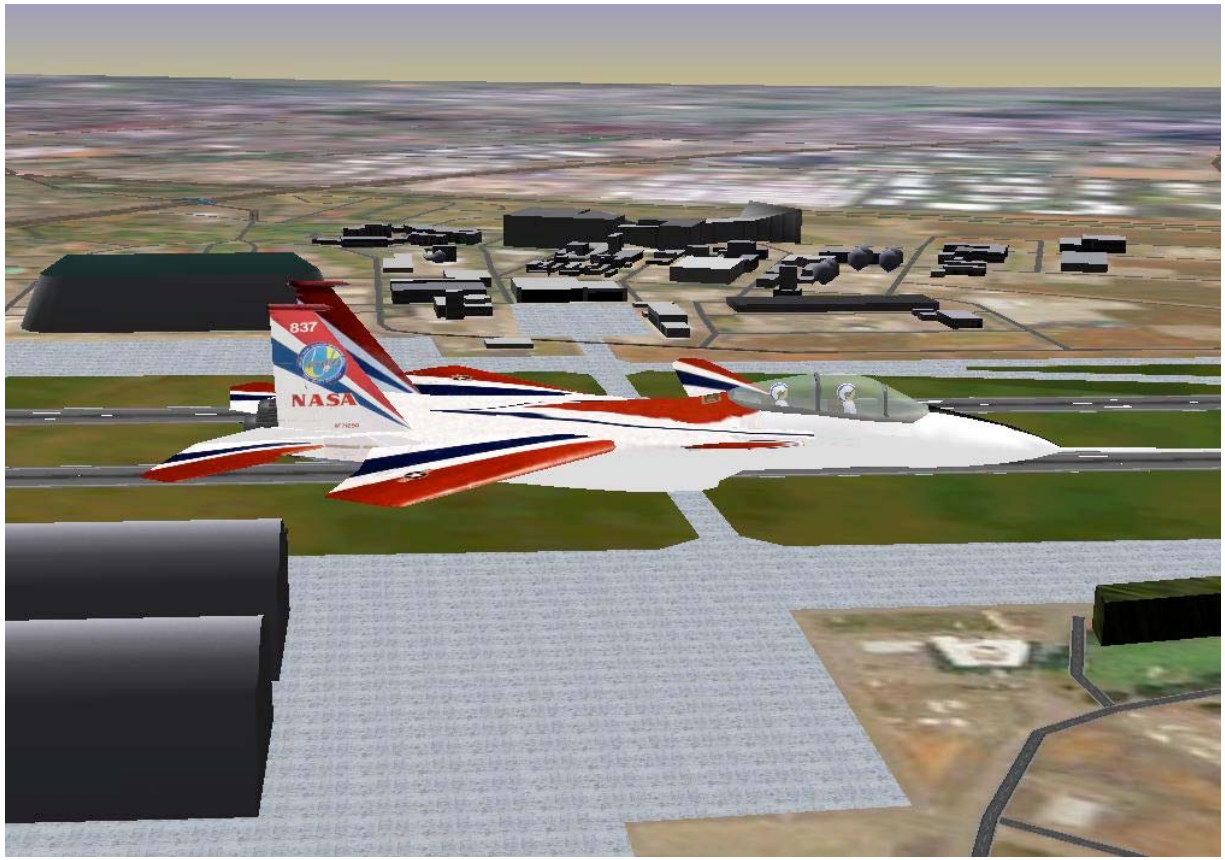
Easy with drag-and-drop interface



CMU 2002 student project

Interoperability

In search of a general solution



Apex pilot flies an F-16 over NASA Ames

Apex interops with:

Riptide

X-Plane

Mozilla

AMBR (HLA)

(+ Sherpa)

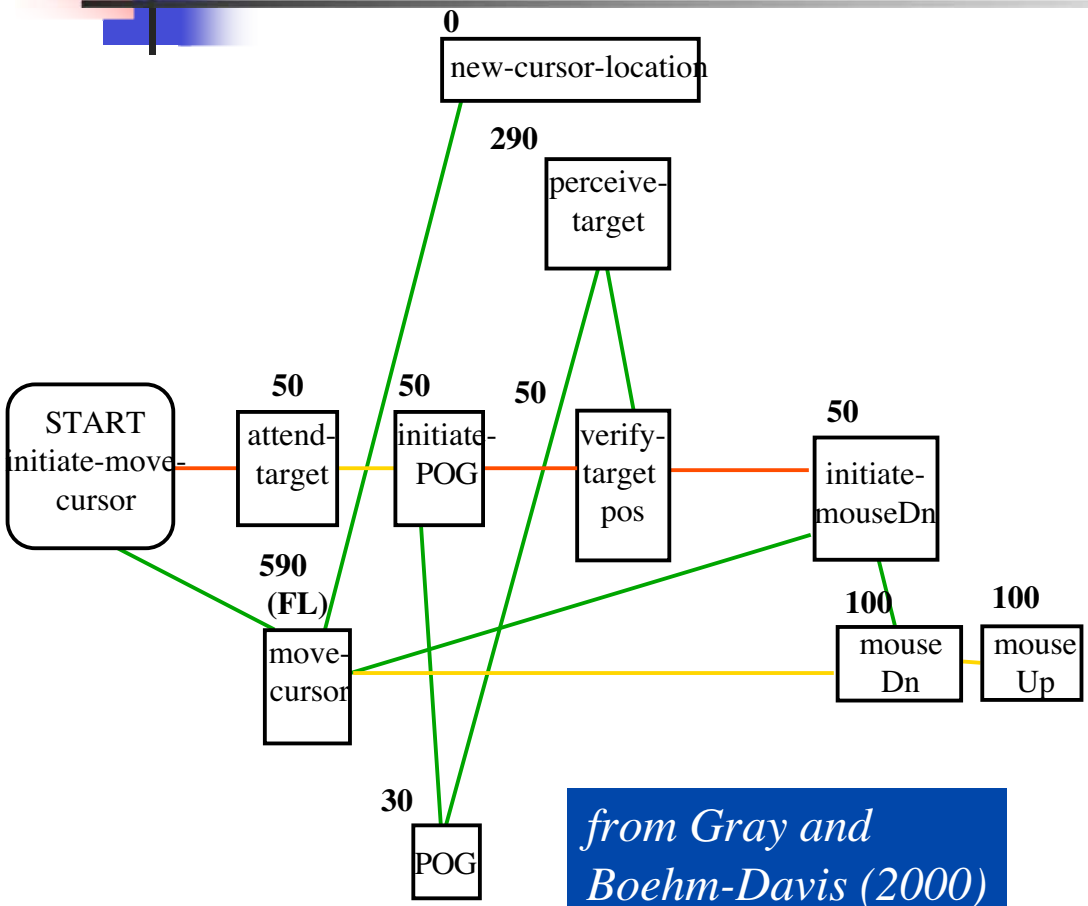
Reusable effort:

Apex API

Sim compatibility

Com support

Resuable building-blocks



from Gray and Boehm-Davis (2000)

```
(procedure
  (index (fast-move-click-R-hand-on-mouse :target ?target))
  (step c1 (initiate-move-cursor ?target))
  (step m1 (move-cursor ?target) (waitfor ?c1))
  (step c2 (attend-target ?target))
  (step c3 (initiate-eye-movement ?target) (waitfor ?c2))
  (step m2 (eye-movement ?target) (waitfor ?c3))
  (step p1 (perceive-target-complex ?target))
  (step c4 (verify-target-position ?target) (waitfor ?c3 ?p1))
  (step c5 (initiate-click ?target) (waitfor ?c4 ?m1))
  (step m3 (mouse-down ?target) (waitfor ?m1 ?c5))
  (step m4 (mouse-up ?target) (waitfor ?m3))
  (step t (terminate) (waitfor ?m4 ?rvr1 ?rvr2)))
```

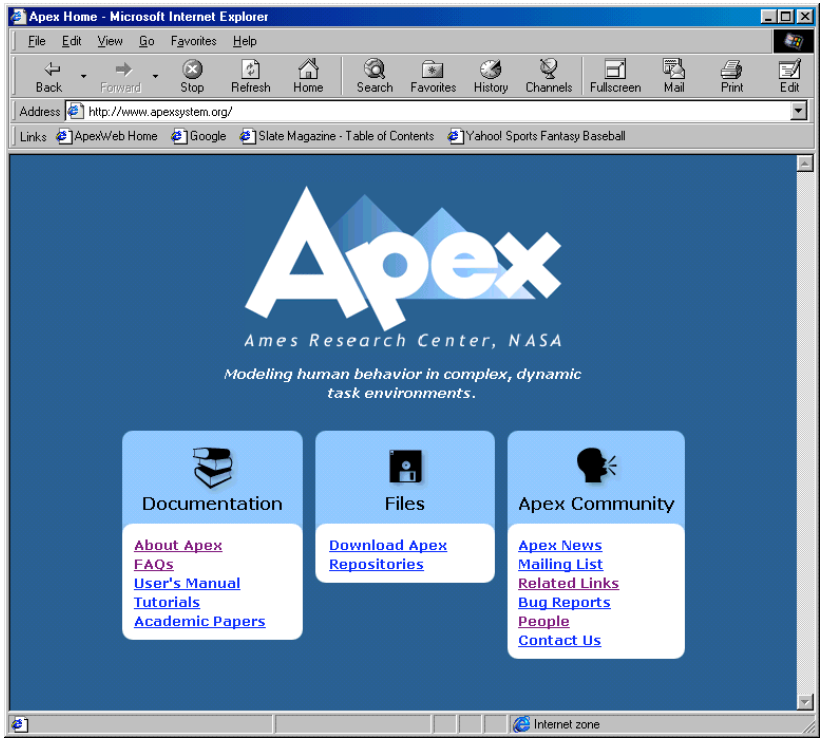
Distributed Development

Why needed

- Library of “building blocks”
- Resource models
- Software interfaces
- Visualization tools

Making it happen

- Software infrastructure
- Educational outreach
- Web-based support



Apex collaborative web site
(CMU HCI project 2001)